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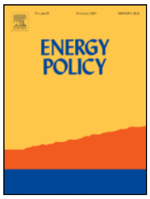

Macroeconomic effects of fiscal incentives to promote electric vehicles in Iceland: Implications for government and consumer costs

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ABSTRACT

Iceland as an island country with abundant renewable energy resources has been totally dependent on imported petroleum fuels to meet its transport fuel demand. Transition to electric vehicles (EVs) is of particular interest for Iceland as electricity can be supplied from low-cost renewable energy resources. To evaluate how the transition to EVs can be achieved through fiscal policy incentives, a dynamic simulation modelling of the integrated energy-transport system with a detailed representation of energy technologies and vehicle fleets is implemented. The model is used for a scenario analysis by incorporating key fiscal parameters including different taxes and subsidies on vehicles and fuels. The fiscal policies to induce EVs, which are applied to both vehicle usage pattern and upfront purchase cost, include petroleum fuel tax levies, vehicle tax exemption, extra fees and subsidies. Five fiscal-induced scenarios to promote EVs, including different subsidy and feebate schemes coupled with fuel tax incentives, are compared with a BAU case. The scenario analysis reveals the impact of different fiscal policy incentives on consumer decision behaviour and the implications of fiscal-induced EV promotion for vehicle ownership costs, government tax revenues/expenditure, and overall economic benefits.

1. Introduction

Transition to a green transport sector utilizing efficient powertrains and alternative fuels could significantly influence the energy sector and macro-economic systems. Besides the prospects for technological improvements, supportive measures such as fiscal incentives, fuel infrastructure provision, restriction/regulation strategies, and marketing efforts can be implemented to promote alternative fuel vehicles (AFVs). Of these factors, the fiscal incentives for fuels and vehicles, notably subsidies and tax levies, primarily affect the adoption and usage pattern of green vehicles (Brand et al., 2013; Langbroek et al., 2016).

Fiscal instruments for the uptake of AFVs, particularly electric vehicles (EVs), have been adopted in many countries (see e.g. Mock and Yang (2014) and Zhang et al. (2014) for two comprehensive worldwide comparison of fiscal incentives for the adoption of EVs). In addition, a variety of recent studies have investigated the effectiveness of alternative fiscal policy instruments to promote EVs, taking into account different perspectives such as consumer choice behaviour, greenhouse gas (GHG) mitigation, macroeconomic costs, and social benefit (for a brief review see Section 2).

The potential impact of fiscal instruments, in particular, is of great importance for small economies as they could confront major economic and social challenges in sustaining their transportation using affordable and secure resources and technological options. Iceland is an island country characterized by an isolated energy-system with abundant renewable energy resources. High dependencies on petroleum fuel imports have left Iceland vulnerable to oil price volatilities and rising GHG emissions. Transition to renewable fuels has been of particular interest for Iceland as renewable energy resources such as hydro, geothermal, and wind enable a significant and affordable potential for fuelling EV fleets. Hence, the prioritization of technological options, support measures, and fiscal policies enabling the progress towards a carbon-neutral transport is essential.

The Icelandic government has introduced incentives such as tax exemptions and emission-differentiated vehicle taxes to promote the contribution of green vehicles in the transport sector. Several previous energy-system studies have addressed the effects of technology development, fuel supply-push poli-

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Abbreviations: AFV, Alternative Fuel Vehicle; ICEV, Internal Combustion Engine Vehicle; bbl, Barrel; ISK, Icelandic Krona; BEV, Battery Electric Vehicle; km, kilometre; EV, Electric Vehicle; LDV, Light-Duty Vehicle; g, Gram; MNL, Multinomial Logit; GHG, Greenhouse Gas; PHEV, Plug-in Hybrid Electric Vehicle; HDV, Heavy-Duty Vehicle;; VAT, Value Added Tax; HEV, Hybrid Electric Vehicle; $, US Dollar.

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cies, banning strategies, fuel prices, and carbon tax on the evolution of AFVs in Iceland. An agent-based modelling study has predicted the market share evolution of EVs within light-duty vehicle (LDV) fleets in response to changes in gasoline price, EV purchase cost, recharging concerns, and excise duty tax (Shafiei et al., 2012). The study only addressed the competition between conventional gasoline vehicles and battery electric vehicles (BEV), assuming an exogenous representation of energy prices and fuel infrastructure. A hybrid agent-based and system-dynamics approach evaluated the interactions among consumers, vehicle market and energy supply infrastructure through a simplified case study for Iceland (Shafiei et al., 2014b, 2013). A system-dynamics model of the Icelandic energy system (UniSyD_IS) has been used to compare the potential market share of electric, hydrogen and biofuel vehicles in response to different supply-push strategies (Shafiei et al., 2015a, 2014a) as well as the cost-effectiveness of supporting renewable transport fuels (Shafiei et al., 2015b). The normative approach of Shafiei et al. (2017a) simulated the trajectories towards a carbon-neutral transport sector through stringent policies banning petroleum fuel vehicles.

The potential impacts and implications of fiscal instruments have not been thoroughly explored in Iceland in the context of energy system analysis. Fiscal policies in terms of tax and subsidy incentives can be imposed on both vehicle usage and purchase cost. These incentives help to overcome the cost disadvantage of EVs with direct short- and long-term implications for government expenses and consumer costs. To analyse the economic consequences of integrating EVs within the Icelandic transport fleet, a dynamic simulation-based analysis is performed using the system-dynamics model of Iceland's energy system (UniSyD_IS). The UniSyD_IS model enables an effective simulation of interactions among fuel supply, infrastructure expansion, market dynamics, and consumer behaviours. The main objective of this paper is to compare the macroeconomic cost responses to different fiscal incentives aimed at promoting EVs. The analysis is aimed at assessing the implications of different fiscal incentives towards electro-mobility for consumer costs and government net revenues. The main focus of the scenario simulations will be on the economic impacts of both upfront cost and vehicle usage incentives.

The rest of the paper is organized as follows. Section 2 presents a short review of recent studies focusing on the fiscal-induced promotion of EVs. In Section 3, an overview of fiscal instruments that are currently in place in Iceland are presented. The analytical tool and approach is briefly introduced in Section 4, and the main assumptions on vehicle costs are given in Section 5. The scenarios are explained in Section 6, and then the results of the model analysis are discussed in Section 7. Finally, the conclusions and policy implications are provided in Section 8.

2. Recent studies on fiscal policy analysis of EVs

The scope of the following review focuses on recent studies that have investigated the effectiveness of alternative fiscal policy instruments to promote EVs. Different studies have been classified into three main groups: the US studies, the EU studies, and the East Asian studies.

Ross Morrow et al. (2010) applied the National Energy Modelling System (NEMS) to estimate the energy, economic, and CO_2 implications of different policies from 2010 to 2030 in the US. They studied 16 vehicle technology options, including PHEVs. They concluded that purchase tax credits are ineffective in cutting emissions, while proposing an additional tax on petroleum fuels will result in the largest reductions in both CO_2 emissions and oil imports, driven by a significant reduction in annual travel distance. Having focused on the vehicle ownership cost, Tseng et al. (2013) studied five representative vehicle types (conventional, hybrid with and without plug-in, and electric), and then concluded that with federal tax incentives, all EV types driven 120,000 miles over 12 years are affordable and the additional lifetime costs compared to conventional vehicles are about 5%.

Lutsey et al. (2015) focused on the effectiveness of various promotion activities in the US cities using statistical models, considering both fiscal and non-fiscal instruments. Based on an analysis of 25 major U.S. metropolitan areas, they detected a significant variation in the effectiveness of promotion activities to advance the adoption of EVs, mainly due to the size and density of cities.

Focusing on the east Asia, the analysis by Hong et al. (2012) using a mixed logit model, indicated that annual tax incentives for EVs in South Korea are twice as effective as an initial lump-sum incentive for purchasing price as the consumer choice probability for EVs would rise by 14% due to tax incentives, compared to 7% for lump-sum incentives. Later, Hao et al. (2014) investigated the rationale of China's two-phase EV subsidy scheme and estimated their impacts on the EV market penetration, by estimating the ownership cost of BEVs. Later, Helveston et al. (2015) have used data from choice-based conjoint surveys fielded in 2012–2013 in China and the U.S. to model consumer preferences for conventional, HEV, PHEV, and BEV technologies focusing on the impacts of federal subsidies.

Shepherd et al. (2012) have used a system-dynamics approach to assess the impact of subsidies and taxation on the uptake of PHEVs and BEVs during a 40-year period in the UK. They have evaluated the effectiveness of vehicle subsidies in different scenarios. Brand et al. (2013) applied the UK Transport Carbon Model to quantify the impacts of fiscal incentives on passenger car sales and emissions until 2050 in the UK. The findings concluded that car purchase tax and feebate policies are the most effective policies in reducing life cycle GHG emissions.

In the case of Austria, Gass et al. (2014) analysed three fiscal policy scenarios; (i) upfront price support, (ii) CO_2 tax, and (iii) tax increase on fuel for ICE. They have calculated the total ownership costs for ICEV and EV from 2011 to 2020, based on the survey responses from the main automobile manufacturers and importers in Austria. The authors argued that introducing the estimated tax levels for CO_2 and fuel consumption would be less attractive compared to an upfront vehicle price support.

Market share of EV accounted for more than 22% of all new car sales in Norway in 2015 (ICCT Europe, 2016), confirming that EVs are attractive to consumers when incentives are powerful enough. Figenbaum et al. (2015) explored possible explanations to the Norwegian development considering the incentives given and the attitudes among users. They found that the current taxation scheme in Norway offers a great opportunity to influence vehicle purchase, and to compensate for marketing challenges.

Recently, Lévay et al. (2017) focused on the implications of fiscal incentives on the total cost of ownership, net price, and sales of eight EV-ICEV pairs in eight European countries using 2014 data. The collected information enlightens that exemptions from registration and annual taxes support big EVs, while initial lump-sum subsidies favour small EVs.

The presented review provides an overview of the recent studies focusing on the implication of different policies on the adoption of EVs, GHG emissions and consumer expenditures in the United States, East Asia, and Europe. The applied methodologies include system-dynamics, regression models, mixed logit model and choice-based surveys. The explored policies covered a wide range, including purchase tax credit, emissions taxes, vehicle registration fees, and tax on conventional fuels.

While many studies have focused on the impact of fiscal incentives on consumer's behaviour and vehicle ownership costs, the implications of transitions to EVs in the long-term for government revenues and overall macroeconomic benefits from both government and consumer perspectives have been less explored. The present research will provide a broader understanding of the key implications of more detailed fiscal instrument from both consumer and government aspects. For such purpose, the key fiscal parameters including excise duty tax, value added tax, weight tax, distance tax, disposal charge, carbon tax and various fuel taxes will be explored.

3. Fiscal instruments in Iceland

Vehicle and fuel taxation is a key source of tax revenue for the European countries. While tax rates and fees related to the registration, ownership and use of cars are diverse across Europe (Kunert and Kuhfeld, 2007), the generated taxes accounts for up to 5% of the gross national product (OECD, 2016). In 2016, the collected tax, including excise duties and value added tax (VAT), on vehicles imported to Iceland reached 63.7 billion ISK which is 17% higher than 2015 (The Icelandic Automobile Association, 2016). The key fiscal parameters in the current analysis are described in the following sections. An average exchange

3.1. Vehicle tax

Taxes on vehicles include excise duty, value added taxes, and annual road tax.

3.1.1. Excise duty tax

Most motor vehicles are subject to an excise duty upon import in Iceland. The excise duty on LDVs is currently based on CO_2 emissions declared by car manufacturers for the combination of city and road driving as shown in Table 1 (Alþingi, 1993).

Considering the current structure of taxes in Iceland, EVs are exempted from the excise tax. The structure of excise tax is different for heavy-duty vehicles (HDVs). The excise tax is 30% for small busses that can carry 10 passengers or less and have total weight less than 5 t, while if they are owned by companies, the excise tax is 5%. It is zero for trucks with a total weight above 5 t (Alþingi, 1993). Based on the HDV fleet composition (ICETRA, 2017), the average excise duty for the HDV fleet is 0.5%.

3.1.2. Value added tax (VAT)

Currently, the VAT is 24% for all conventional vehicles in Iceland. Since 2012, there has been a discount of ISK 1.44 million on the VAT for BEVs, and a discount of up to ISK 0.96 million for PHEVs (Alþingi, 2016).

3.1.3. Weight tax

For vehicles, with a total weight of 3.5 t or less, the weight tax is ISK 11,620 per year for the release of up to 121 g-CO_2/km, and ISK 278 per gram of excess CO_2. Considering the registered CO_2 emissions for EVs, their owners only need to pay the minimum road tax (Alþingi, 2016). To calculate the average weight tax for the fleet, the average weight of LDV fleet needs to be estimated. Based on the composition of the new registered vehicles (ICETRA, 2017), the average weight of a LDV is 1.4 t and the average engine power is 90 kW. Considering the estimated average weight, the weight tax is ISK 11,620 plus the CO_2 emissions dependent term.

For heavy vehicles (weight exceeding 3.5 t), weight tax is linearly related to the vehicle weight. Based on the HDV fleet composition, the average weight of a typical HDV is 9 t, and engine power is 375 kW. Considering the average weight of HDV fleet, the weight tax is estimated to be ISK 134,360 per year.

3.1.4. Distance tax

Distance tax which depends on the weight and the annual distances travelled, is applied only to HDVs with a weight of 10 t or more (Article 13 - Alþingi, 2004). Based on the HDV fleet composition in 2015, 46% of the fleet is heavier than 10 t and the average weight of heavy vehicles exceeding 10 t is 12.5 t. In addition, the weight distance tax for HDVs is ISK 1.6 per km, according to Alþingi (2004). Thus, the distance tax will be estimated as 0.46 × 1.6 × annual km.

3.1.5. Disposal charge

According to “Iceland: Recycling Fees Act, No. 162/2002″, since January 2003, a disposal charge of ISK 700 is levied on each vehicle annually (Alþingi, 2002).

3.1.6. Summary of assumptions on vehicle tax

Table 2 provides a summary of the vehicle tax structure in Iceland, which is based on our estimations and the literature. The annual road tax is defined as the total of weight tax, distance tax and disposal charge.

3.2. Fuel tax

The prices of gasoline and diesel fuels in Iceland have three tax components: excise duty tax, VAT and carbon tax charge.

The excise duty tax on gasoline is 70.05 ISK/litre (Alþingi, 2016), while it is 60.10 ISK/litre for diesel (Alþingi, 2016). A VAT rate of 24% is applied to all fuels including electricity (Alþingi, 2014). The carbon tax rates on gasoline and diesel are 5.5 ISK/litre and 6.3 ISK/litre (Alþingi, 2009), equivalent to $20/tonne-CO2eq.

4. Analytical tools

The energy system model for Iceland (UniSyD_IS) based on the system-dynamics approach is used to simulate the implications of transport fiscal policies during 2015–2050. UniSyD_IS is a partial-equilibrium system-dynamics model with a detailed representation of energy resources, conversion technologies, fuel infrastructure, and vehicle fleets. It is capable of endogenously simulating the vehicle fleet evolution using the sector modelling of fuel supply, energy markets, refuelling/recharging infrastructure, and fuel demand.

The model has been tested with applications in different case studies and it has been applied to New Zealand and Iceland (see Shafiei et al. (2017b) for an overview). The model structure is conceptually divided into four main sub-sectors.

4.1. Energy supply

This sector calculates the amount of fuels that can be supplied at various market prices and production costs. It incorporates four key components involving resource supply curves, existing plant capacities, planned or future capacities, and production costs. The future costs of renewable resources are modelled using resource supply curves in which generation cost increases with cumulative production. Besides the imported petroleum fuels, the fuel supply system is modelled from renewable energy sources including hydro, geothermal, wind, and waste biomass.

4.2. Refuelling/recharging infrastructure

This sector determines the refuelling station service availability as an important factor that changes consumer preferences towards AFVs. Station profitability is used to represent fuel station viability. A positive gap between the projected profitability and a desired level of profit leads to increase the construction rate of new stations (Keith, 2012). Refuelling stations are assumed to be retired at the end of their lifetime if they are not profitable due to a lower fuel demand (Shafiei et al., 2016, 2015a).

4.2.1. Vehicle choice and fuel demand

A vehicle choice algorithm forecasts the market share evolution of different vehicles within LDV and HDV fleets. A multinomial logit (MNL) framework gives the probability that consumers adopt new vehicles based on their preferences towards vehicles' attributes. The vehicle attributes included in the consumer utility function are vehicle purchase price ($), annual maintenance cost ($/year), fuel cost per kilometre ($/km), battery replacement cost for EVs ($), vehicle driving range (km), and refuelling service availability (relative to the conventional petroleum fuel infrastructure).

The preferences coefficients in the utility function are calibrated using basic economic assumptions. In this context, the vehicle purchase price coefficient is calibrated using the elasticity data for the vehicle demand in Iceland.

Table 1
Excise tax factor based on registered CO_2 emissions (Alþingi, 1993).

Group	A	B	C	D	E	F	G	H	I	J
Emission level (g/km)	0–80	81–100	101–120	121–140	141–160	161–180	181–200	201–225	226–250	+250

Table 2
Vehicle tax structure in Iceland.

Tax type	Unit	Vehicles	
		LDVs	HDVs
Excise duty tax	% of import price	0–65%	0.5%
Value added tax	% of price including excise tax	24%	24%
Weight tax	ISK	11620 + 278 × (g/km-121)	134,360
Distance tax	ISK	0	0.74 × annual km
Disposal charge	ISK	700	700

The purchase price coefficient is then used as a scaling factor for estimation of the other preferences coefficients. For more details see (Shafiei et al., 2014a).

The model adjusts the annual travel demand over time according to changes in the fuel cost per km. For simplicity and based on available data in (Dahl, 2012), we have assumed a constant elasticity of -0.33 to adjust the annual travel demand with respect to changes in the fuel cost per km. Annual distance travelled, vehicle stock, fuel economy improvement, vehicle technology shifts, and vehicle fuel switching are taken into consideration in forecasting the total fuel demand.

4.2.2. *Energy markets*

This sector attempts to balance the demand with the supply curves of production plants by changing price signals. The algorithm is based on a market-oriented economic system in which fuel supply viability is determined by market clearing price and supply profitability (Shafiei et al., 2015a). In the short term, the energy price signals are transferred to the corresponding production plants to determine the amount of fuel supply. In the long-term, the forecasted fuel prices play a crucial role in the installation of new capacities. For a detailed description of the algorithm see (Shafiei et al., 2015c).

Table 3
Vehicle fleet and powertrain categories.

Powertrain Group	Fuel Type	LDV	HDV
internal combustion engine vehicle (ICEV)	gasoline	✓	n/a
	diesel	✓	✓
	dedicated biogas	✓	✓
	biogas + gasoline	✓	n/a
hybrid electric vehicle (HEV)	gasoline	✓	n/a
	diesel	✓	✓
plug-in hybrid electric vehicle (PHEV)	gasoline + electricity	✓	n/a
	diesel + electricity	✓	✓
battery electric vehicle (BEV)	electricity	✓	n/a

The model is capable of simulating the interactions of around 2000 variables during the time horizon of 2015–2050 with a two-week time step. While the model is capable of simulating all alternative fuel markets, the analysis in this paper focuses on the electro-mobility, incorporating the electricity supply infrastructure and the corresponding vehicle technologies in the demand side.

5. Vehicle choice set

Table 3 shows the classification of fleets and powertrains in the current analysis. Vehicle fleets are divided into LDV and HDV vehicles. LDVs weigh less than 3.5 t and the typical car representing the LDV fleet in Iceland is modelled assuming an average weight of 1.4 t and the engine power of 90 kW. It is assumed that HDVs weigh more than 3.5 t with an average weight of 9 t and an average engine power of 375 kW.

Due to existing technological restriction in terms of battery size, power density, and driving range, BEV is excluded from the HDV application (California Environmental Protection Agency, 2015), and PHEV is the only EV option for HDVs in the current analysis. The use of liquid biofuels and their blend with petroleum fuels are excluded from the current analysis. Only biogas as a renewable fuel, which has been produced from biomass wastes in Iceland is kept within the fleet composition.

5.1. *Vehicle purchase cost*

Fig. 1 shows the assumed capital purchase cost of different vehicles over time. The vehicle purchase costs have been calculated based on the initial and floor cost data from (Dodds and Ekins, 2014; Mcdowall and Dodds, 2012) for manufacturing, powertrain, fuel tank, exhaust, chassis and other vehicle components. The fixed components of capital cost have been scaled according to the assumed average weights of vehicles, but the powertrain costs have been scaled according to the average engine power of vehicles in Iceland. Technological learning for vehicles is applied exogenously by assuming a global mass-production level for EVs by 2030 (Shafiei et al., 2017b).

The key capital cost component of EVs is the size of the battery requirement, which is calculated based on the required driving range. The specific cost data for different battery sizes during 2015–2030 are presented in Table 4.

5.2. *Vehicle operation and maintenance cost*

The annual maintenance costs are displayed in Table 5. The data for LDVs have been adopted from (EU Coalition Study, 2010) with own modifications in terms of the annual distances travelled, the exchange rate, and the cost deflator for Iceland. The corresponding values for HDVs have been approximated by scaling up the costs of LDVs according to the ratio of vehicle weights and annual distances travelled.

The average insurance fees for typical LDVs and HDVs are assumed as $1025/year and $4100/year, respectively (VIS, 2017). The corresponding annual costs for the vehicle inspection are $102/year and $162/year (Adalskodun, 2017). An average exchange rate of ISK 117 per US$ is assumed for all calculations.

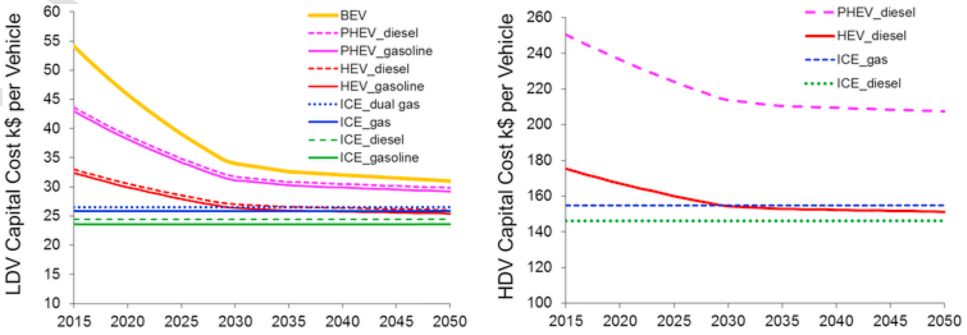


Fig. 1. Average capital purchase cost of vehicles in 2014 k$/vehicle, excluding tax and subsidies, assuming range values of 300 km for BEV and 60 km for PHEV. The data are based on (Dodds and Ekins, 2014; Mcdowall and Dodds, 2012) with own modifications (note: different scales on the chars).

Table 4
Assumptions on the specific battery cost [a].

Battery size (kWh)	Specific cost in 2015 ($/kWh)			Specific cost beyond 2030 ($/kWh)		
	low	medium	high	low	medium	high
10	577	721	866	216	325	433
20	438	547	656	164	246	328
30	372	465	557	139	209	279
40	332	414	497	124	187	249
50	303	379	455	114	171	227
60	281	352	422	106	158	211

[a] Initial and future data are based on average battery costs in (Bubeck et al., 2016; Nykvist and Nilsson, 2015) with own modifications. The battery size effects are from (Wu et al., 2015).

Table 5
Annual maintenance cost in $/year, based on data from (EU Coalition Study, 2010) with modifications.

	ICE-gasoline	ICE-diesel	HEV-gasoline	HEV-diesel	PHEV-gasoline	PHEV-diesel	BEV
LDV	657	694	657	694	620	655	500
HDV	–	9251	–	9251	–	8729	–

6. Scenarios

Six scenarios are defined, as shown in Table 6, based on different taxes and subsidies on fuels and vehicles. The *BAU* scenario reflects the fiscal policies currently active in Iceland. In this scenario, the excise duties and VAT are levied on the fuels as explained in Section 3.2. The VAT and excise duties on vehicles are implemented according to the assumptions explained in Section 3.1. In the *BAU + Tax* scenario, further fiscal incentives for EVs in terms of the higher carbon tax and petroleum excise duties are introduced. It is assumed that the carbon tax increases from an initial value of $20/tonne-CO2eq to $200/tonne-CO2eq by 2050. A 100% increase is also assumed for the petroleum fuel excise duties by 2050 (i.e., the average annual growth rate of 2% during 2015–2050).

To promote the market introduction of EVs, the *Subsidy* scenario incorporates further incentives to BAU in terms of direct subsidies linked to the purchase price of BEV and PHEV within both LDV and HDV fleets. In comparison, the *Subsidy + Tax* scenario includes both the purchase price subsidies and the higher carbon tax and petroleum excise duties.

The *Feebate* scenario is defined as another fiscal policy option to further stimulate the uptake of EVs. In this scenario, a fee equivalent to 20% of the conventional ICEV price is imposed on both petroleum ICEVs and HEVs, which have higher fuel consumption and emissions compared to PHEVs and BEVs. Next, an equivalent rebate value is provided to the purchase price of light-BEVs and heavy-PHEVs. The *Feebate + Tax* scenario makes the Feebate scenario incentives stronger through the higher excise duty and carbon tax levies on the petroleum fuels.

In all scenarios, the oil price is constant at $50/bbl over the study period. The presented costs for batteries and vehicles in Fig. 1 and Table 4 are used for a baseline analysis. To incorporate the effects of different battery characteristics for EVs, additional sensitivity cases are taken into account as presented in Table 7.

Table 6
Definition of scenarios.

Scenarios	taxes on fuels	taxes on vehicles	incentives and subsidies
BAU	current fuel tax as in Section 3.2 constant carbon tax of $20/t	VAT & excise duty tax levies based on Section 3.1	VAT exemption for EVs according to Section 3.1
BAU + Tax	***BAU*** assumptions + 100% rise in petroleum excise tax + carbon tax rise to $200/t by 2050	identical to ***BAU***	identical to ***BAU***
Subsidy	identical to ***BAU***	identical to ***BAU***	***BAU*** assumption + price subsidy of 20% for BEV & PHEV within both LDV & HDV fleets
Subsidy + Tax	identical to ***BAU + Tax***	identical to ***BAU***	identical to ***Subsidy***
Feebate	identical to ***BAU***	***BAU*** assumption + purchase fee for ICEV & HEV equivalent to 20% of conventional ICEV price	***BAU*** assumption + price subsidy for light-BEV & heavy-PHEV equivalent to 20% of conventional ICEV price
Feebate + Tax	identical to ***BAU + Tax***	identical to ***BAU***	identical to ***Feebate***

Table 7
Assumptions for sensitivity analysis.

Battery characteristics	Range in km (BEV, PHEV)	Battery cost assumptions based on Table 4
low range - low cost (LR-LC)	100, 40	lower bound cost
low range - med cost (LR-MC)	100, 40	medium cost
low range - high cost (LR-HC)	100, 40	higher bound cost
med range - low cost (MR-LC)	300, 60	lower bound cost
med range - med cost (MR-MC)	300, 60	medium cost
med range - high cost (MR-HC)	300, 60	higher bound cost
high range - low cost (HR-LC)	500, 80	lower bound cost
high range - med cost (HR-MC)	500, 80	medium cost
high range - high cost (HR-HC)	500, 80	higher bound cost

7. Simulation results

7.1. Vehicle fleet profile

Fig. 2 compares the market share evolution of BEVs and PHEVs within the LDV and HDV fleets. The vehicle upfront fiscal incentives in the *Subsidy* and *Feebate* scenarios significantly raise the market share of BEV technology within the LDV fleet, compared to BAU. The results indicate that *Feebate* is the most effective strategy to promote the market penetration of BEV. Additional fuel tax incentives in terms of petroleum fuel excise duties and carbon tax lead to slight increases in the market share of BEV in all scenarios, substituting mainly for HEVs. The petroleum fuel tax incentives will not influence the share of PHEV within the LDV fleet. The reason is that PHEV has a dual-fuel capability that the assumed range of 60 km for the electric driving mode accounts for 65% of daily distance travelled. Since the vehicle rebate incentives taking effect in the *Feebate* scenario are only allocated to BEVs, a lower market penetration of PHEV is observed compared to the *Subsidy* scenario.

The share of PHEV within the HDV fleet is highly influenced by different scenario assumptions as it is the only EV technology assumed for HDVs. The market share of heavy PHEVs, unlike LDV's, is sensitive to the fuel tax incentives due to a lower contribution of the electric driving range in total distance travelled.

7.2. Government net revenues

Fig. 3 compares the government tax revenues and subsidies in different scenarios. The vehicle upfront tax revenues, composed of vehicle excise duty and vehicle purchase VAT, show decreasing patterns in all scenarios due to assuming the emission-differentiated tax duties as well as the VAT exemptions for EVs as explained in Section 3.1. It implies that the higher share of EVs by stronger fiscal incentives reduces the government income from vehicle purchase tax levies.

The fuel excise duty is reduced by 25%, 32%, and 38% over the period in *BAU*, *Subsidy*, and *Feebate*, respectively, in accordance with the reduction of demand for petroleum fuels. The inclusion of fuel tax incentives in *BAU + Tax* and *Subsidy + Tax*, enhances the fuel excise tax revenues slightly by 19% and 10%. The fuel excise tax is not changed in the *Feebate + Tax* scenario because additional petroleum excise duty is offset by the significant reduction of 48% in petroleum fuel use by 2050. Assuming a substantial rise in the carbon tax in *BAU + Tax*, *Subsidy + Tax*, and *Feebate + Tax* leads to the carbon tax contributions of 15%, 21%, and 17% in total net government revenue by 2050.

The vehicle road tax slightly decreases in all scenarios due to the transition to a lower emission fleet and losing the emission-dependent component of the road tax revenues as explained in Section 3.1. The fuel VAT revenue in the scenarios with vehicle purchase incentives (*BAU, Subsidy, and Feebate*) is reduced slightly due to changes in the fuel demand. However, a minor growth in the fuel VAT revenue is expected for the other three scenarios with fuel tax incentives as the VAT rate is applied to all components of fuel prices (i.e., fuel cost, excise tax, and carbon tax).

Under the *Subsidy* and *Subsidy + Tax* scenarios, the government direct subsidies on EVs account for 33% and 27% of gross government revenues by 2050. Under *Feebate* and *Feebate + Tax*, additional vehicle purchase fees applied to petroleum ICEVs and HEVs bring significant income for the government during the initial years of the simulation period. It gradually declines over time as EVs are adopted, which in turn boost the subsidies in terms of the EV rebates as defined in Table 6. In the *Feebate* scenario, the extra purchase fee will be superior to subsidies (rebate) until the year 2040 where all fees should be rebated to the consumers who adopt EVs. Thereafter, the government needs to supplement its income from the fees to cover the rebate expenses. Under the *Feebate + Tax* scenario, the balance between fee and rebate will occur earlier at 2035. It leads to 17% reduction in the vehicle fee revenues and 18% growth in the rebate expenses by 2050, compared to the *Feebate* scenario.

Fig. 4 compares the overall net tax revenues from fuels and vehicles. As shown in the left chart of Fig. 4, introducing fiscal incentives for the vehicle upfront cost makes the fuel tax revenue component slightly worse than *BAU* in line with the reduction of petroleum fuel consumption. Simulating the impact of rising carbon tax and fuel excise duty incentives indicates that a growth of at least 80% in the fuel tax revenue would be expected in all scenarios by 2050.

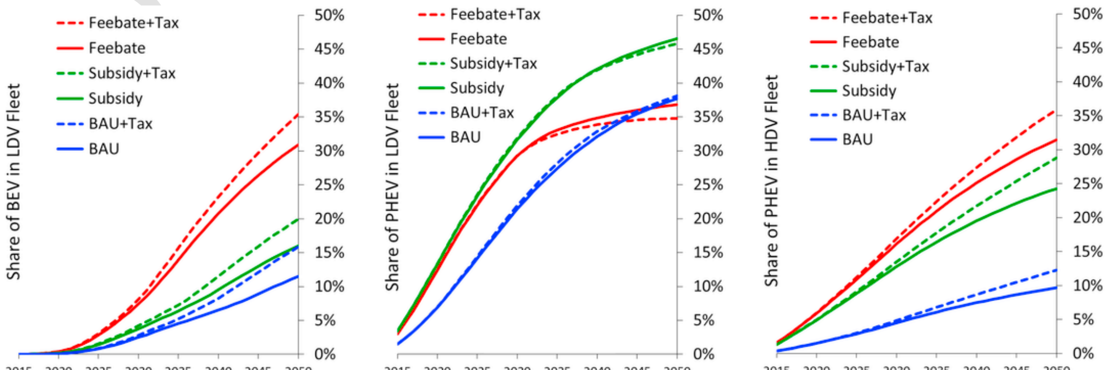
The middle chart in Fig. 4 shows that the tax revenues from vehicle purchase is decreasing over time in all cases. Under *BAU*, the tax shrinkage of 45% is forecasted during the study horizon. Under the *Feebate*-dependent scenarios, while the government could benefit from the excess revenues from the petroleum vehicle fees during 2015–2030, a sharp drop in the net revenues is expected by 2050 to compensate for the rebate expanses. Under the *Subsidy*-dependent scenarios, it is envisaged that the government will lose all of its net revenues from the vehicle taxation by 2050 as all of the related revenues should be spent on the EV subsidies.

The right chart in Fig. 4 reveals the overall tax revenues including the fuel and vehicle taxes as well as the annual road tax revenues. The main implication of the simulation results is that the fuel tax incentives in all scenarios make significant increase in the overall tax revenues. The supplementary fuel tax in the *BAU + Tax* scenario could preserve the overall government revenue at its initial level. Under *Subsidy* and *Feebate*, the fuel tax incentives make the overall tax revenues approach the *BAU* trend in the long-term. It implies that the carbon tax and petroleum excise duties can be effective fiscal instruments to compensate for the lost tax revenues in all scenarios.

7.3. Consumer vehicle ownership cost

Fig. 5 presents the simulated patterns for the consumer fuel cost (including the cost of petroleum fuels and electricity as well as fuel taxes), the vehicle purchase cost (including the vehicle taxes and subsidies), and the total vehicle ownership cost (including the fuel cost, vehicle purchase cost, maintenance cost, and the costs of inspection and insurance).

The vehicle upfront capital incentives in the *Subsidy* and *Feebate* cases result in the minor fuel cost reductions of 5% and 8% by 2050, compared to *BAU*. By contrast, the fuel tax incentives, in terms of higher carbon tax and petroleum excise duty, increase the consumer fuel cost by 34–37% in different cases.



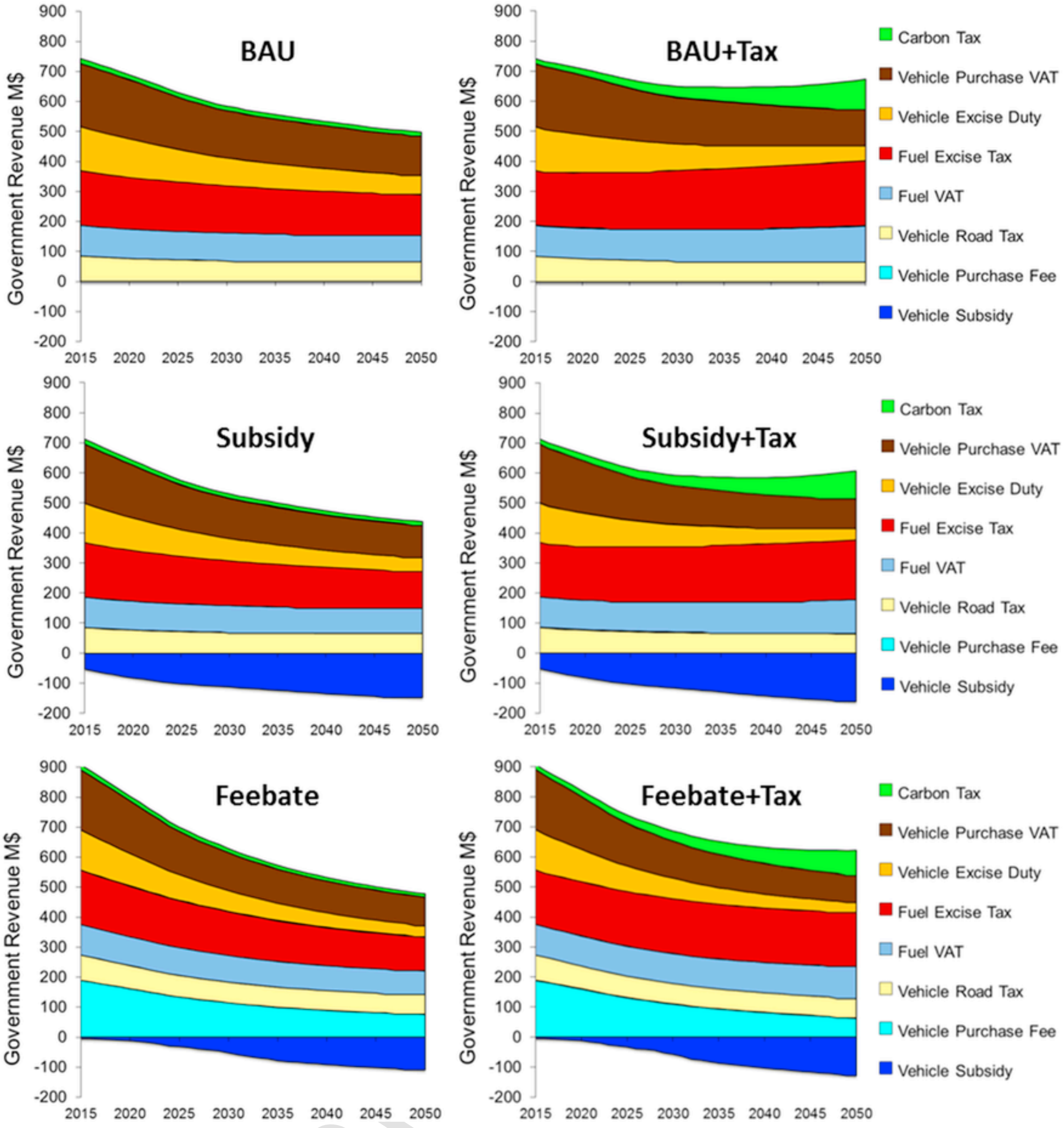


Fig. 3. Structure of government revenues and expenditures in different scenarios.

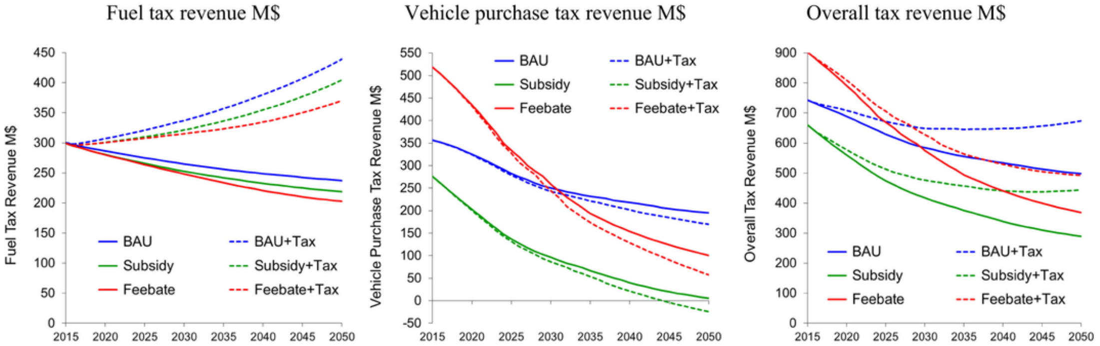


Fig. 4. Comparison of net government revenues from fuels and vehicles in different scenarios (Note: different scales on the charts).

The vehicle purchase cost component is mostly influenced by the vehicle purchase incentive policies. The *Subsidy*-dependent scenarios represent the lowest vehicle purchase cost from a consumer perspective by a reduction of 13% compared to *BAU* by 2050. Because of imposing extra fees on the petroleum vehicles, the *Feebate*-dependent scenarios initially entail an extra vehicle purchase cost of 18% compared to the *BAU* case. Owing to the market penetration of EVs, the government rebates gradually offset the adverse effects of ve-

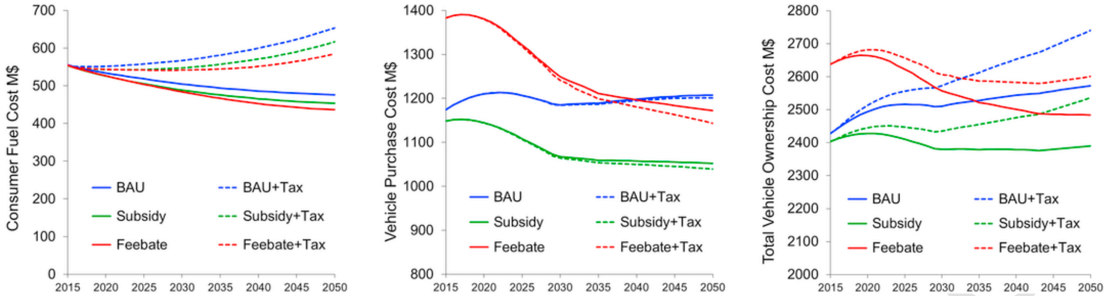


Fig. 5. Comparison of consumer vehicle ownership costs in different scenarios (Note: different scales on the charts).

hicle fees, leading to a downward trend toward the below of the *BAU* level by 2040.

From an overall vehicle ownership cost, the *Subsidy* scenario would be the most attractive strategy, leading to the lowest ownership cost. *BAU + Tax* would be the most expensive scenario in the long-term. The forecasted trends for total vehicle ownership cost in the other scenarios converge to, relatively, the same value.

7.4. Overall economic benefits

The economic benefits in the current analysis are evaluated from three perspectives: i) government benefit, ii) consumer benefit, and iii) overall consumer and government benefits. The net benefit is calculated as the difference in total consumer cost and net government revenue between each scenario and the BAU case.

The percentage changes in net benefits of different scenarios are illustrated in Fig. 6. The consumer benefits due to different fiscal policies move inversely to the government net benefits. While *BAU + Tax* is superior from the government perspective by the net benefit of 35% (M$180/year) in 2050, it will result in a consumer loss of 7% (M$167/year). Conversely, while the *Subsidy* scenario brings the greatest benefit of +7% (M$183/year) for consumers, it leads to a major government loss of 42% (M$210/year) by 2050 compared to BAU.

To estimate the overall consumer and government benefit, the government net tax revenues are deducted from the total consumer costs, and then the resulting values are compared to BAU.

In all scenarios, the fuel tax incentives improve the government benefit and worsen the consumer benefits by a large amount. However, from an overall view, the fuel tax incentives get the overall consumer and government benefits slightly promoted. The changes in the overall benefits reflect the economic effects of the market share development of EVs in different scenarios.

To evaluate the trade-off between government and consumer benefits, further analysis is presented as shown in Table 8. The *BAU + Tax* policy that raises the cumulative discounted government revenue (compared to BAU and assuming a 7% discount rate) makes the consumer cost worse off. To generate $1 of revenue for the government, the consumer cost increases by $0.95, which is shown by a negative value in Table 8. Raising $1 additional government revenue in the *Feebate* and *Feebate + Tax* scenarios leads to the consumer losses of $2.33 and $1.7, respectively. In the *Subsidy* and *Subsidy + Tax* cases, the government revenue loss of $1 (due to direct subsidies) makes the consumer benefits of $0.66 and $0.55, respectively. The resultant effect of government revenue change on consumer benefit depends on the overall interaction between tax/subsidies and consumers' behavioural change (i.e. travel demand, shift to alternative powertrains, and fuel switching).

To evaluate the magnitude of loss and benefits compared to the absence of fiscal incentives, further comparative analysis is performed as illustrated in Fig. 7. For each scenario, a reference case is defined. For the associate reference case to each scenario, no fiscal policy intervention occurs to promote EVs, and similar tax mechanisms are implemented for both conventional and alternative fuel vehicles. However, each reference case resembles the results of its associated scenario, producing the same market shares for all vehicles over time. It has been achieved by implementing exogenous constraints in the market penetration of vehicles assuming equal-taxation mechanisms for all vehicles in the reference cases. All reference cases assume a VAT rate of 24% on all vehicle types. Instead of emission-differentiated excise tax duties on vehicles, the constant rates of 30% and 0.5% are levied on LDVs and HDVs, respectively. The fuel taxation remains as the same as *BAU*. The simulation results show that all government losses are totally transformed into consumer gains. The overall benefit is zero for all scenarios as similar vehicle market structure is assumed for each scenario and its associated reference situation.

7.5. Effectiveness and efficiency of policies

Different fiscal policies to promote EVs can be compared in terms of effectiveness and efficiency. The market share of EVs within the vehicle fleets and

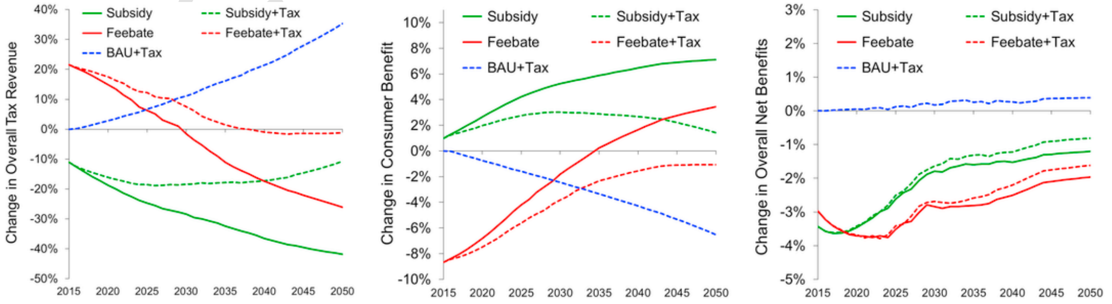


Fig. 6. Net economic benefits compared to BAU (Note: different scales on the charts).

Table 8
Consumer net benefit to government net revenue ratio.

	BAU + Tax	Subsidy	Subsidy + Tax	Feebate	Feebate + Tax
Consumer-to-government benefit ratio	−0.95	0.66	0.55	−2.33	−1.70

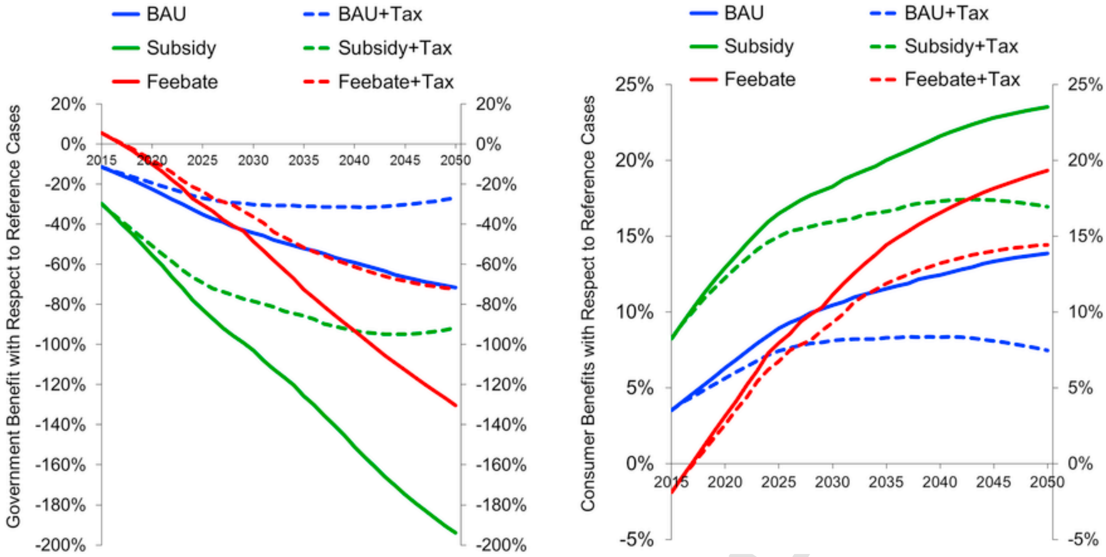


Fig. 7. Economic benefit/loss compared to the reference cases with lack of fiscal incentives (Note: different scales on the charts).

the level of GHG mitigation provide simple proxies for the policy effectiveness. The efficiency analysis evaluates the economic efficiency of policies in terms of total or specific costs associated with transition processes. Total net transition cost and GHG mitigation cost (in $/tonne-CO2eq) represent the efficiency of policies in this analysis. According to Fig. 8, the *Feebate + Tax* and *Subsidy + Tax* scenarios are the most effective strategies in GHG mitigation (or petroleum fuel use saving), and the *Subsidy* scenario is the least effective policy option. However, the efficiency analysis from the total transition cost perspective indicates that *BAU + Tax* is the best economically-efficient scenario followed by *Subsiy + Tax*. Conversely, *Feebate* is the worst policy option in terms of cost-efficiency.

Performing a pairwise comparative analysis between the scenarios showed that the fuel tax incentives improve both the cost-efficiency and effectiveness of policies. It means that, as shown in Fig. 8, the inclusion of fuel tax incentives in *BAU + Tax*, *Subsidy + Tax*, and *Feebate + Tax* improves both the economic benefits and the GHG mitigation, compared to *BAU*, *Subsidy* and *Feebate*, respectively. However, in a multiple comparison considering all scenarios, there are conflicts between efficiency and effectiveness measures. For example, in the *Feebate + Tax* scenario, enhancing the policy effectiveness (i.e. higher GHG mitigation) is expected to occur at a higher transition cost (i.e. less efficiency). By incorporating cumulative discounted cost and cumulative GHG mitigation, the cost-effectiveness of GHG mitigation is calculated. According to Fig. 8, the *BAU + Tax* and *Subsidy + Tax* policies exhibit the best cost-effectiveness at reducing each tonne of CO2-eq. The *Subsidy* scenario falls in the least cost-effective option.

7.6. *Sensitivity analysis*

To evaluate the sensitivity of main findings with respect to assumptions on battery cost and battery driving range, further analyses are performed based on the cases defined in Table 7. Fig. 9 shows the impact of battery cost and driving range assumptions on the share of electricity in total transport fuel demand by 2050. This figure reveals the overall market penetration and usage effects of BEV and PHEV within both LDVs and HDVs. In general, the following important points can be deducted from Fig. 9:

i) The more fiscal incentives, the higher the share of electricity will be in the total fuel demand.
ii) At a certain level of battery range, the share of electricity is improved by battery cost reduction.
iii) The low range value assumptions (i.e., LR-HC, LR-MC, LR-HC) lead to the lowest electricity share in total demand.
iv) Although the results indicate that a medium battery range would be the most economically attractive option for BEV for LDVs, however, by taking into account the effects of PHEVs within both LDVs and HDVs, the higher battery range values give a higher share of electricity in total fuel demand.

Fig. 10 displays the sensitivity of government and consumer benefits (compared to BAU) with respect to the assumptions on the cost of batteries and driving range as explained in Table 7. Similar to the analysis in Fig. 6, the per-

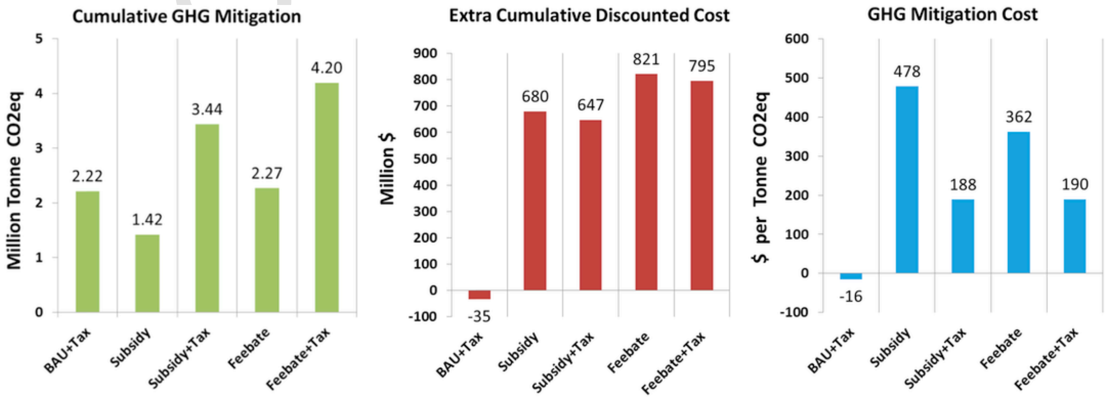


Fig. 8. Cumulative GHG mitigation, extra cumulative discounted cost (compared to BAU), and GHG mitigation cost.

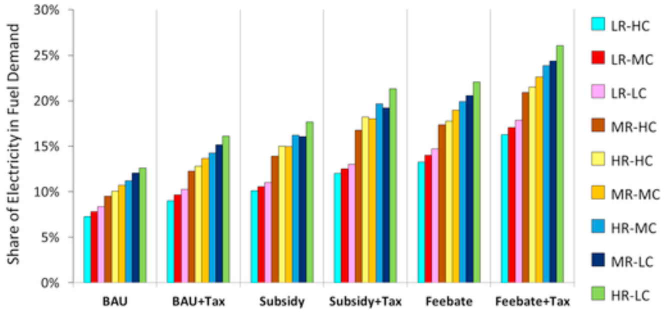


Fig. 9. Impact of battery cost and driving range assumptions on the share of electricity in total transport fuel demand by 2050.

centage changes have been calculated by comparing each sensitivity case to its corresponding case in the *BAU* condition. The resulting patterns for different sensitivity cases conform to the overall effects of electricity share (as shown in Fig. 9) and battery cost/range assumptions. In general, the following important findings can be concluded:

i) When battery range is low (i.e., LR-HC, LR-MC, LR-HC), higher government benefit is forecasted in all scenarios because of lower electricity share in total demand. By contrast, the cases linked to the low cost with higher battery range values (i.e. MR-LC and HR-LC) are most advantageous for the consumers.
ii) Net benefits in *BAU + Tax* shows the lowest variations with the sensitivity assumptions, mainly due to the small differences in the market share of EVs compared to BAU.
iii) In the *Subsidy* scenario, the government benefit is sensitive, to a small extent, when a low battery range assumption is chosen.
iv) In the *Subsidy + Tax* scenario, the government benefit increases with range reduction (electricity market share effect) and battery cost reduction (lower subsidy effects).
v) *Subsidy + Tax* and *Feebate + Tax* scenarios are largely influenced by the battery range and cost assumptions. Low range values largely improve the government benefit in these scenarios. Because of the small share of EVs and the lower amount of subsidy requirement in these cases, the government losses diminish sharply after 2030.
vi) The *Feebate* and *Feebate + Tax* scenarios are largely sensitive to the higher values of range and cost (i.e. HR-HC, MR-HC and HR-MC) to enhance the government benefit mainly due to a lower contribution of BEV within the LDV fleet. Conversely, the government loss will be highest in the cases with the low cost and higher battery range values (i.e. MR-LC and HR-LC which give the consumers the best advantage). From a consumer perspective, the vehicle capital-intensive case of HR-HC would be at a disadvantage.
vii) The overall net benefits (government and consumers) will be minuscule (less than 1%) in the *BAU + Tax* scenario. The other scenarios show negative overall benefits, albeit with improving trends over time for most of the cases. In the *Feebate*-dependent scenarios, the cases coupled with the higher range and cost values (i.e., HR-HC and HR-MC), which are costly to consumers, aggravates the overall benefit from 2040.

8. Conclusions and policy implications

The potential impact of fiscal policy instruments is of great importance for Iceland as a small economy, which could face challenges in sustaining green and affordable transport services with long-term economic gains. A dynamic simulation model of the integrated energy-transport system was employed to assess the implications of fiscal-induced promotion of EVs for government and consumer costs in Iceland. In this context, incentives for both upfront cost and vehicle usage were taken into consideration. Vehicle purchase VAT, vehicle excise duty, extra purchase fees, and purchase subsidy are the main fiscal factors assumed for the upfront purchase cost of vehicles. From the vehicle usage perspective, the assumed fiscal policy parameters are carbon tax, petroleum fuel excise duties, fuel VAT, and annual road tax.

The analysis compared five scenarios aimed at inducing EV markets through the provision of different fiscal incentives with a BAU scenario assuming the current fiscal policies. The fiscal incentives for vehicle purchase price were introduced as price subsidy for EVs and feebate scheme, which includes extra fees for petroleum fuel vehicles and rebates for EV price. The fiscal incentives from the vehicle usage perspective include higher levels of petroleum excise duty and carbon tax. Various sensitivity cases were then defined within each scenario to evaluate the findings with respect to changes in the cost and driving range characteristics of batteries for EVs.

The simulation results confirmed that providing vehicle upfront cost incentives would be a more effective strategy, compared to vehicle usage tax incentives, to promote the market penetration of EVs within both LDVs and HDVs. The vehicle usage tax incentives, in terms of petroleum fuel excise duties and carbon tax, can slightly enhance the market for light-BEV and heavy-PHEV. These incentives will not influence the share of light-PHEV due to the competition with BEVs.

The contribution of electricity in total transport fuel demand, which reveals the overall market penetration and usage effects of BEV and PHEV within both LDVs and HDVs, is significantly affected by both fiscal-induced polices and characteristics of EVs (i.e., battery cost and driving range). Following the BAU condition, the share of electricity in the fuel demand by 2050 will be within the span of 7–13%, depending on battery range and cost value assumptions. The supplementary fuel tax incentives in BAU raise this share span to 9–16%. The EV price subsidy strategy would be more effective in stimulating PHEVs, rather than BEVs, leading to the electricity share span of 10–18% by 2050. However, the EV price subsidy together with the fuel tax incentives favours BEV, giving a higher electricity share of 12–21% in the fuel demand. Both the feebate schemes, without and with fuel tax incentives, favour light-BEV and heavy-PHEV, and lead to the electricity share spans of 13–22% and 16–26%, respectively, by 2050. From a vehicle stock perspective, the maximum market share of 40% for both light-BEV and heavy-PHEV can be achieved by 2050 through the implementation of the feebate scheme with fuel tax incentives. The corresponding value for light-PHEV is estimated as 53% under the subsidy-related fiscal incentives.

In terms of GHG mitigation, the subsidy and feebate scenarios coupled with fuel tax incentives show the most effectiveness while the subsidy scenario is the least effective policy option in reducing GHG emissions. The petroleum fuel tax incentives improve both the GHG mitigation and the cost-effectiveness of fiscal policies in emissions reduction. The BAU and subsidy scenarios coupled with fuel taxes show the best cost-effectiveness at reducing each tonne of CO_2-eq. The subsidy scenario falls in the least cost-effective option.

The findings indicate that continuing the current fiscal policy scheme under the BAU scenario leads to a government tax revenue shrinkage of 28–35% during the study horizon, depending on different assumptions on battery cost and driving range. The implementation of the fiscal policies taking into account the fuel tax incentives makes large increases in the government tax revenues from fuels, slight decreases in the tax revenues from vehicle purchases, and significant improvement in the overall government tax revenues from the transport sector. Under the current BAU condition, the fuel tax incentives could help to relatively preserve the current government revenues over time. Comparing to BAU, the fuel tax incentives are identified as effective fiscal policy instruments to compensate for the lost tax revenues due to the uptake of EVs in all scenarios. Particularly, to minimize the government losses under the subsidy and feebate schemes, compared to the BAU trend, these strategies should be coupled with the fuel tax incentives, which large petroleum fuel excise duty and carbon tax levies will be required.

The consumer economic preferences in different fiscal-induced EV promotion policies exhibited inverse patterns to those of government benefits. From the consumers' perspective, the EVs' price subsidy policy would be most advantageous because of a higher market share potential for EVs coupled with a lower vehicle ownership cost. Conversely, a sole fuel tax incentive scheme added to BAU would be the most expensive strategy from the consumer views as a minor market share development

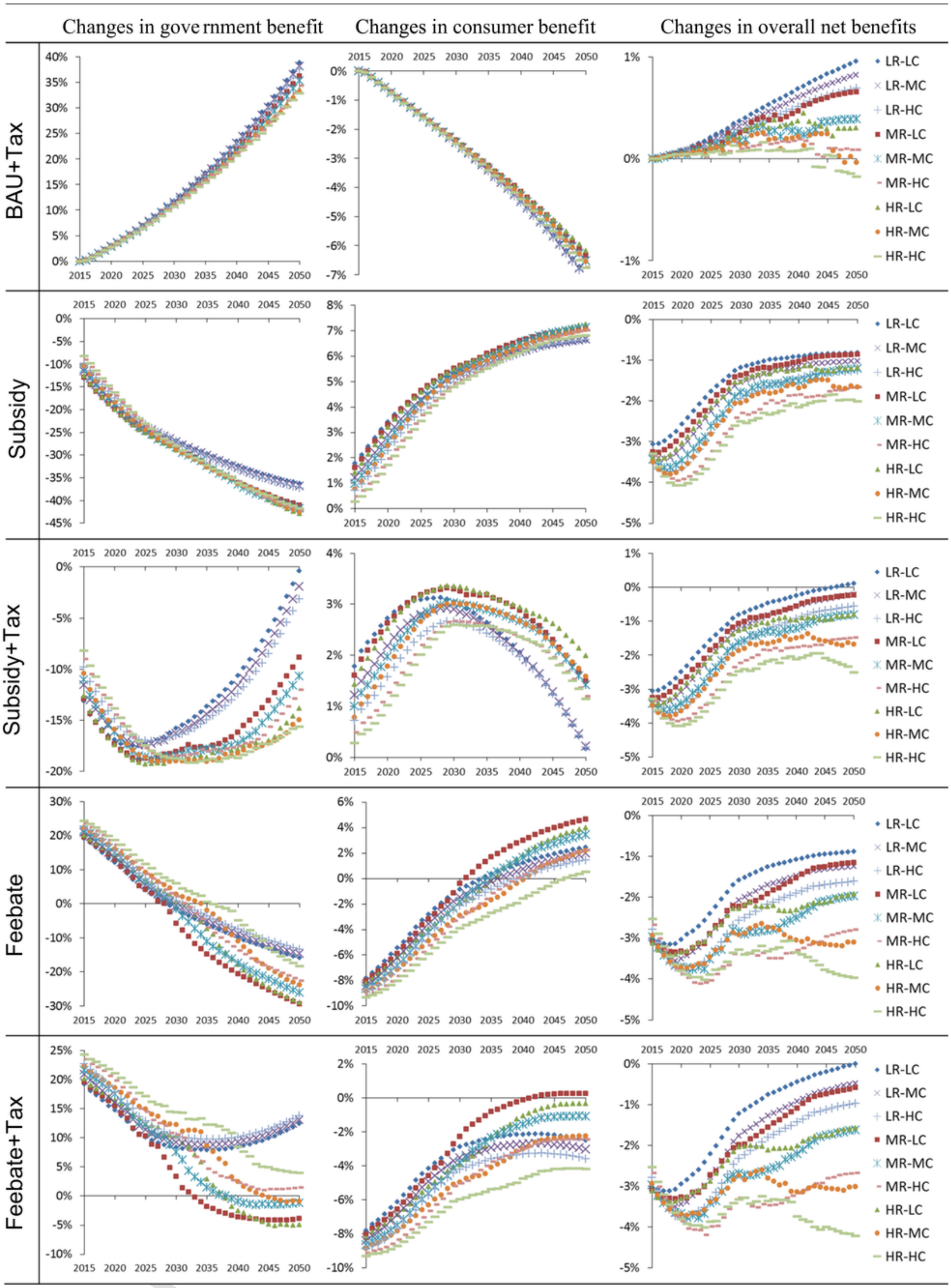


Fig. 10. Impact of battery cost and driving range assumptions on government and consumer benefit compared to BAU (Note: different scales on the charts).

The findings from an overall consumer and government perspective, which reveals the economic effects of the market share development of EVs, showed that only BAU with fuel tax incentives could make a positive balance, albeit with a lower market share potential for EVs. The other scenarios, which give higher shares of EVs, exhibited negative overall balances, although with improving trends over time. Incorporating the fuel tax incentives are identified as useful policy instruments to promote the overall economic benefits in all scenarios.

The analysis showed different response patterns to changes in battery cost and driving range assumptions. Thus, it is important to consider these dependencies when implications of different fiscal policies are evaluated. The results showed high sensitivities when lower battery range values are assumed. In general, lower battery ranges favour government due to a lower revenue loss, especially in the feebate and subsidy scenarios with supplementary fuel tax incentives. Medium and higher battery range values when battery cost is low favour consumers the most. From an overall perspective, vehicle capital-intensive cases representing higher driving range values when battery cost is high would be at a disadvantage.

Finally, the presented study provides a broad understanding of the key implications of detailed fiscal instruments from both consumer and government aspects. The comparative analysis provides important insights into energy and transport planning for transition towards EVs in Iceland with the aim of utilizing indigenous renewable energy sources. By investigating a broad range of options, the results can inform policy-makers on the implications and potential costs/benefits of fiscal policies aimed at supporting EVs. However, it should be noted that the economic costs/benefits from both government and consumer perspectives do not necessarily reflect the priority or advantage of each scenario as they have been estimated based on different levels of EV promotion and GHG mitigation. If specific goals or targets had been set for the GHG mitigation, then the least-cost strategy satisfying the goals would have determined the preferred policy. Since the resulting effectiveness levels are different, there are conflicts between efficiency and effectiveness measures and both criteria could not be fully satisfied. In this framework, which there is no specific target or goal to be satisfied, the cost-effectiveness of GHG mitigation could be a useful measure to compare the scenarios. However, future works in our research agenda would be designing a multi-criteria decision analysis framework to incorporate a broader range of factors to prioritize different policy options. In addition, since the tax levies or subsidies in reality are dependent on specific vehicle attributes (e.g., weight, engine capacity, fuel economy, purpose of use, etc), further breaking down the vehicles into more detailed sub-categories would improve the accuracy of results.

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